

## SYSTEM AND METHOD FOR MONITORING AND REPORTING AIRCRAFT QUICK ACCESS RECORDER DATA

### BACKGROUND OF THE INVENTION

#### 1. Field of Invention

[0001] This invention relates to systems and methods for monitoring, analyzing and reporting a vehicle, such as, for example, aircraft, data.

#### 2. Description of Related Art

[0002] The use of computers has expanded the scope of maintenance-related monitoring and reporting of vehicle, such as, for example, aircraft, data, especially the reporting of malfunction or fault information. Fault information may be used to determine which vehicle systems and components require further testing and/or observation by, for example, flight crew or maintenance personnel, located, for example, on the ground and/or in the air, and/or replacement or repair. Fault information generally is based on the crews' observations and maintenance personnel analysis, using maintenance manuals and operator initiated testing. However, because fault information determinations are highly dependent upon crew member observation, crew member memory and crew member analysis, it is relatively inefficient and unreliable.

[0003] To facilitate the maintenance of an aircraft, most aircraft systems now are made up in part of components that can be removed and replaced quickly. These components are called Line Replacement Units (LRUs). An LRU is a highly complex module often incorporating several data processors for controlling and/or monitoring one or more components or systems of an aircraft. An LRU may be provided to monitor and/or control one or more devices such as an actuator, valve, motor, pump, etc., associated with a particular component or assembly of a vehicle, such as, for example, an aircraft. An LRU identifies faults during operation in flight, and requires the integration of multiple fault data to independently report the fault source, i.e., a specific component or assembly. An LRU typically also generates output signals which are monitored to determine if the component is not operating properly.

[0004] As the number of aircraft systems that make use of LRUs have increased and have become more complex, so has the volume of maintenance information. The volume of information makes it difficult for the flight crews and ground crews to obtain the specific information they need to analyze and diagnose causes of identified faults. Thus, a system to collect and consolidate the voluminous fault information is needed. One such system is based on a centralized scheme for fault data collection and analysis. In that system, the LRUs are recorded on a Quick Access Recorder (QAR). The QAR records the information from the multiple LRUs and other components which are monitored, and stores the monitored information on a medium, such as, for example, a high density optical storage disc. In that system, the LRU data from multiple LRUs is automatically collected during flight or at the end of the flight, and analyzed by the maintenance personnel to determine repair of faulty component(s), if needed.

[0005] An example of a system that utilizes QAR can be found in U.S. Patent 6,115,656, the subject matter of which is incorporated herein in its entirety, that records and reports fault information pertaining to various components of an aircraft. The method involves recording a large, diverse amount of information outputted from various LRUs and other components of the aircraft during takeoff, flight, and landing through the use of a bulk storage device, such as an optical quick access recorder (QAR), on an electronic medium. The electronic medium is then removed from the aircraft after landing and the information read by an appropriate apparatus. Based on this information, a maintenance personnel attempts to determine whether or not a fault indication recorded during flight is in fact a legitimate fault requiring the affected LRU to be removed from the aircraft for further diagnostic testing. Although, this method reduces the incidents of no-fault diagnostic test results and saves man hours which would otherwise be spent testing LRUs and other components which are in fact operating properly, this method uses expensive, proprietary equipment that is permanently installed on the aircraft, and which requires extensive certification processes by a maintenance crew. Further, this requires a highly-skilled maintenance crew to board the aircraft after the flight and download the recorded LRU fault information.

### SUMMARY OF THE INVENTION

[0006] Accordingly, the present invention provides systems and methods for monitoring and reporting a vehicle's (e.g., an aircraft) quick access recorder (QAR) data based on a removable and portable hardware component.

[0007] This invention separately provides systems and methods that monitor and report QAR's fault information in real-time.

[0008] One exemplary embodiment according to the systems and methods of this invention performs real-time monitoring and analysis of the QAR data received from a QAR device for specific QAR events.

[0009] Other exemplary embodiments of the systems and methods of this invention separately utilize an air-ground data transmitting device to transmit notification messages to the ground when the fault indication events occur.

[0010] Other exemplary embodiments of the systems and methods of this invention separately advise the users (e.g., pilots and/or maintenance crew) of notable fault indication events.

[0011] Other exemplary embodiments of the systems and methods of this invention separately monitor any number of QAR events that include a number of vehicle parameters and conditions.

[0012] Other exemplary embodiments of the systems and methods of this invention separately provide for notification of vehicle, such as, for example, an aircraft complex system, fault behavior to a ground crew for corrective action.

[0013] Other exemplary embodiments of the systems and methods of this invention provide for interfacing with flight crew or adaptive flight control systems for in-flight corrective action of aircraft complex systems. Other exemplary embodiments of the systems and methods according to this invention provides a QAR device, an air-ground data transmitting device, an onboard data communications network, and a hardware component.

[0014] Other exemplary embodiments of the systems and methods according to this invention provide a hardware component that is removable from the vehicle and is portable.

[0015] In yet other exemplary embodiments of the systems and methods according to this invention, the removable and portable hardware component is a PC-based host that operates a QAR Manager application.

[0016] In yet further exemplary embodiments of the systems and methods according to this invention, the removable and portable hardware component is an Electronic Flight Bag (EFB).

[0017] In other various exemplary embodiments of the systems and methods according to this invention, the EFB hosts a QAR Manager application.

[0018] In various exemplary embodiments of the systems and methods of the invention, the QAR Manager is a program, such as, for example, eFlightDeck, that uses the EFB and communication technologies to manage applications on the EFB.

[0019] In further exemplary embodiments of the system and method according to this invention, the air-ground data transmitting device is connected to an air-ground antenna, wherein the air-ground data transmitting device is capable of operating independently of the main aircraft's power.

[0020] In yet a further exemplary embodiment of the systems and methods of this invention, the air-ground data transmitting device is connected to the main power source or the vehicle, such as, for example, aircraft.

[0021] In yet a further exemplary embodiment of the systems and methods of this invention, the system will also monitor in real time, operational performance parameters of the attached QAR in order to display actual status of QAR hardware, including memory allocation and free space availability for recorded data as well as other statistical data such as when data was last off-loaded.

[0022] These and other features and advantages of this invention are described in, or are apparent from, the following detailed description of various exemplary embodiments of the systems and methods according to this invention.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0023] Various exemplary embodiments of the systems and methods according to this invention will be described in detail with reference to the following figures, wherein:

[0024] Figure 1 is a schematic representation of a system of one exemplary embodiment for monitoring and reporting fault information according to this invention;

[0025] Figure 2 is a schematic representation of a system of one exemplary embodiment for monitoring and reporting the LRUs according to this invention;

[0026] Figure 3 is a flowchart illustrating one exemplary monitoring and reporting process according to this invention;

[0027] Figure 4 is a flowchart illustrating another exemplary monitoring method according to this invention; and

[0028] Figure 5 is a screen image of EFB hosted QAR Manager application that shows an exemplary embodiment for monitoring and reporting fault information according to this invention.

#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0029] Fig. 1 illustrates one exemplary embodiment of the systems and methods according to this invention. The monitoring and reporting of QAR data system 10 includes a Quick Access Recorder (QAR) device 100, an onboard data communication network 200, an air-ground data transmitting device (AGDTA) 300, a removable hardware component 400, and an air-ground antenna 500.

[0030] A QAR is a mass storage device that records a large and diverse plurality of output signals from line replacement units (LRUs), actuators, valves, sensors, and other various components of a vehicle to determine any indication of legitimate faults. In one exemplary embodiment of the systems and methods according to the invention, the QAR device 100 may be, for example, an Avionics miniQAR Mark II, that records information and transmits information in real-time over an onboard data communication network 200 to the removable hardware 400. It should also be appreciated that the information can be recorded on, in addition to, or as an alternative to, QAR 100, for example, magnetic tape storage medium, an optical storage disc, and any current or future developed memory device.

[0031] In various exemplary embodiments, the information can be requested and transmitted via direct connection, such as but not limited to, RS232 line or Ethernet to the removable hardware 400 which can be, but is not limited to, a standard commercial-off-the-shelf personal computer PC carried by pilots and/or other aircrew members which is used to perform various operational functions on and off of the flight deck.

[0032] The on-board data communication network 200 enables onboard devices to exchange different types of information, including, but not limited to information stored in the QAR device 100. The removable hardware 400, which may be, for example, a personal computer that uses information fusion and on-board reasoning processing for diagnosis, prognosis, fault isolation, and identification of component or components responsible for the faulty conditions or alert conditions so that flight crews and/or maintenance personnel are cued to ensure that parts are available for repair or replacement or that the vehicle (e.g.,

aircraft) is taken out of service, if required. The on-board data communication network 200 includes, but not limited to, ARINC 429 data bus, MIL STD 1553 (IEEE 1553) data bus, or Ethernet network. Future embodiments may include the capability to utilize wireless communications such as, but not limited to, Bluetooth and 802.11 or other communications technologies as they become available.

**[0033]** It should be appreciated that the on-board communication network 200 may exchange other information within a vehicle. For example, on aircraft, the exchanged information can include, but is not limited to, physical sensors, flight profile information, flight data recorder data, and other secondary indications of system behavior. The information is sent to a reasoner (not shown) typically a software application hosted in the EFB, which fuses the collected information to establish the state of aircraft and condition of the aircraft.

**[0034]** The air-ground data transmitting device (AGDTD) 300 transmits and receives information to and from a vehicle. The information is exchanged as a binary or character-oriented message. The data transmitting device 300 uses various wireless technology, such as, but not limited to, ACARS, GPRS, VDL M2, CDMA, Iridium as the communication medium. The system is also capable of utilizing wireless technologies such as, but not limited to, 802.11 Ethernet when the aircraft is on the ground in proximity of ground Ethernet access. As an exemplary embodiment according to this invention, the air-ground data transmitting device 300 is a FlyTimer ACARS Communication Unit.

**[0035]** It should be appreciated that the AGDTD 300 can transmit the information in real-time to the flight crews and/or maintenance crew on the ground as well as to other automated systems such as an airline host computer which may have the capability to automatically process certain data. It should also be appreciated that the AGDTD 300 can operate independently of the main vehicle power supply or connected to the main vehicle power supply.

**[0036]** The AGDTD is connected to an air-to-ground antenna 500 to transmit in real-time the QAR information to maintenance personnel on the ground using various communications media as appropriate. For example, in flight, the standard ACARS VHF antenna or Iridium antenna is utilized and on the ground, if 802.11 connection is available, via a 802.11 antenna installed on the aircraft or as part of the EFB installation.

**[0037]** The removable hardware component 400 is a device that receives and collects the information of the QAR device 100, which is capable of hosting a suite of

applications. The removable hardware component 400 can be, but not limited to, a standard commercial-off-the-shelf personal computer PC that is carried by pilots and maybe used an Electronic Flight Bag (EFB) which is typically a standard tablet PC that meets FAA criteria as a Class 2 device. The EFB is portable and used as a host computer for various functions on a flight deck. EFB is a small electronic information management device for use by flight crew in performing flight-related tasks. These devices aid pilots and aircraft operators in conducting flight more efficiently and safely. EFBs serve as a repository for electronic documents, such as checklists, operating manuals, and navigation publication. EFBs also serve as multi-function devices that can support an array of applications beyond those of a traditional flight bag, including, but not limited to cabin surveillance, surface moving map, electronic messaging, and display of live weather. Further, the EFBs may support unlimited expansion to other applications that normally execute on a standard PC, such as, but not limited to crew scheduling, electronic log books, weight & balance calculators, and performance applications.

**[0038]** In various exemplary embodiments, the EFB hosts a QAR Manager (QARMAN) application. A QAR Manager is a program, (e.g., eFlightDeck) that uses the EFB and communication technologies to manage all applications on the EFB. EflightDeck consists of a suite of applications that not only eliminate time-consuming paper processes, but takes into consideration the concept of an integrated pilot operational environment (i.e., every-day cockpit tasks) to the next level more easily and quickly, which will result in cost savings for the airlines.

**[0039]** The EFB Manager application is designed to operate software like ARINC's QARMAN and EFB Video Viewer, and with other applications, such as, for example, FlyTimer ACARS CDU, Jeppessen™ JeppView™ and AMT FlightMan™.

**[0040]** Fig. 2 is a schematic representation an exemplary embodiment according to the invention of a system that monitors and reports the status of the multiple line replacements (LRUs). As shown in Fig. 2, the system includes multiple LRUs 600, QAR device 100, data communication network 200, and a removable hardware/personal computer 400.

**[0041]** The LRUs 600 monitor and/or control one or more devices such as, but not limited to, actuators, valves, motors, and pumps that are associated with a particular component or assembly of a vehicle, such as, for example, an aircraft. Reference is made, in this regard, to the list of the systems and components of a military aircraft which are

associated with LRUs that is set forth in the aforementioned U.S. patent 6,115,656. The LRUs 600 are interfaced with a QAR device 100 to record and store the information and determine any faulty or alert conditions. The information is communicated to a personal computer 400 via a data communication network 200. The portable hardware/computer 400 stores the LRU fault data generated during a flight. The data may be obtained from the LRUs continuously in flight or may be gathered at the end of each flight.

**[0042]** In various other exemplary embodiments, the information is communicated to maintenance personnel 410 on the ground in real-time, and the LRU can be removed from the aircraft for further diagnostic testing when the aircraft lands.

**[0043]** In various other exemplary embodiments, the recorded LRU fault data is stored in an Electronic Flight Bag.

**[0044]** Fig. 3 is a flowchart of an exemplary monitoring and reporting method according to this invention. In the exemplary embodiment shown, operation of the monitoring process begins at step S100 and proceeds to step S200 where LRUs are monitored for faults. Next, control proceeds to step S300 where a determination is made of whether any, and how many, LRU fault conditions exist. Then control proceeds to step S400 where the no-fault results are displayed, and then returns to step S200 to continue monitoring the LRU status. However, if any LRU faults exist, control proceeds to step S500 to display the faults and what LRUs they are associated with. Then, control proceeds to step S600 where a determination is made of whether all the faults have been fixed. If so, control proceeds to step S700 and displays this status, and then returns to step S200 to continue to monitor for LRU faults. If not, control proceeds to step S700 where an attempt is made to fix some or all of the faults, and then control returns to step S500 to continue to report LRU fault status. From the displays in step S400 and S700, flight crew or maintenance personnel are able to determine whether or not a fault indication recorded, for example during flight, has occurred and whether or not it has been fixed.

**[0045]** It should be appreciated that the failure of the LRUs or components can be reported to maintenance personnel on the ground for further diagnostics.

**[0046]** It should also be appreciated that the recorded fault information can be reported to the flight crew and/or maintenance personnel in real-time, thus allowing real-time determination of the nature and effect of specific faults and providing enough information to either trouble shoot the fault or ensure corrective action is accomplished at the appropriate time (e.g., next landing or later).



**[0047]** Fig. 4 is a flowchart illustrating an exemplary embodiment of a method of testing the system shown in Fig. 2. The process commences in step S300, and proceeds to step S310 where the LRU condition data is collected. It should be appreciated that the collection of fault data can be in random order or in a prioritized order. In prioritized order, the fault data is displayed during flight in the form of flight crew alerts. Accordingly, faults may be prioritized based on whether or not crew awareness or action is required.

**[0048]** Next, in step S320, the system compares the LRU status data with normal or standardized/reference data, such as, for example, flight system data. The normal or standardized data is a previously recorded data when the LRU is operating in a normal condition or predetermined acceptable data. Then, control proceeds to step S330. In step S330, the control determines whether the data in the comparison step S320 matches or is within an acceptable range of the normal or standardized data. If the data is acceptable, i.e., no LRU faults exist, control jumps back to step S310 and LRU monitoring continues. If, however, the system determines that the data is not acceptable, such as, for example, if the data does not match, e.g., a fault exists, control proceeds to step S340 where a diagnosis of the LRU(s) for which the data is not acceptable is performed. It should be appreciated that the LRU(s) diagnosis(es) can be automatically performed by a computer (not shown) or manually performed by the flight crew member or maintenance personnel using various diagnostic methods.

**[0049]** If, for example, the crew observes the fault, then the LRU(s) may be tested/evaluated by utilizing manual test equipment with or without the benefit of maintenance manual(s). Then control proceeds to step S350, where a determination is made whether LRU removal is required. If so, control proceeds to step S360, where any faulty LRU(s) may be removed and replaced, and the removed LRU(s) may be further diagnosed, and the process ends in step S370. If not, control returns to step S310 where the testing process continues.

**[0050]** Fig. 5 is an exemplary embodiment of a software module of the QAR Manager for monitoring and reporting fault information according to this invention. The QAR Manager software module is a stand alone module that can be seamlessly integrated into an EFB environment as either a stand alone application or integrated with other suite of software, such as, for example, ARINC eFlightDeck. As an exemplary embodiment, the software module discloses a screen image of a EFB hosted QAR Manager application. The QAR Manager application includes the functions of, but not limited to, user interface (e.g.,

command input and message display), QAR status monitor, communications message generation and distribution, parameter management (e.g., configuration), and parameter monitor.

**[0051]** In an exemplary embodiment, Fig. 5 discloses an user interface function of the QAR Manager software module, such as, but not limited to, auto download QAR gate 1000, automatic ACARS message 2000, pilot alert 3000, and monitor specific parameters 4000.

**[0052]** In the auto download QAR at gate 1000 functionality, the user (e.g., pilot) selects the yes or no buttons. When the yes button is selected by the user, the contents of the QAR system, for example, stored data, will be automatically transmitted to ground systems or personnel when an appropriate communications link is established (i.e., 802.11 wireless Ethernet connection between aircraft and system at an airport). It should be appreciated that the user interface function also provides positive indication (between buttons) of the current state of the parameter.

**[0053]** The automatic ACARS message 2000 function allows the user to enable or disable the automatic generation of ACARS messages that would be generated if specific parameters are exceeded. It should be appreciated that the user can turn off the automatic messages due to abnormal conditions such as frequency congestion due to overwhelming number of messages.

**[0054]** The pilot alert 3000 function allows the user to instruct the system to send messages automatically without the need to be advised if desired. If enabled, when the QAR monitor detects a parameter that would generate an ACARS message, it would present a message on the EFB display so that the user was aware of the condition and subsequently send ACARS messages to ground systems or maintenance people.

**[0055]** The monitor specific parameters 4000 function allows the user to enable the monitoring to begin or stop. The specific parameters to monitor are defined interactively using another function described as part of the set-up parameters 6000.

**[0056]** The end button 5000 allows the user to terminate the complete QAR manager software functionality. It should be appreciated that once depressed, the software alerts the user to confirm that he does in fact wish to terminate the application.

**[0057]** Display area 6000 is the main configuration capability that provides a set up button 6010 and re set button 6020. The set up 6010 and re set 6020 buttons both provide a means to configure the overall QAR Manager functionality. Depressing the set up button

6010 causes another dialogue window to appear which provides the user access to setting up specific watch parameters as well as initiating certain housekeeping functions that control the external QAR device, such as, for example, purging the stored content or copying the QAR content to a file on the EFB in order to continue recording should data storage space be limited. The re set button 6020 provides the ability for the user to reset the QAR device to a default state. Pressing the re set button 6020 causes another dialogue window to appear with more selectable options, such as, for example, reset the QAR and load default parameters.

**[0058]** Area 7000 is a Status display which has several components. For example, the status display may display, in real time, the actual status of the QAR monitoring system to the user, for example, but not limited to, the QAR storage capacity in bytes and in extrapolated time, how much QAR memory has been used, how much memory is still available for more storage, when the last successful QAR data download was accomplished, the last significant event that was detected, how many automatic ACARS messages were sent, a visual indicator showing that “REC” ( recording) is in process, and a visual indication of QAR status (i.e., RED = fault).

**[0059]** While this invention has been described in conjunction with the exemplary embodiments outlined above, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Furthermore, although the exemplary embodiments are described for use in a variety of aircraft, it is contemplated that this invention may be used with other methods of transportations through the land and the sea. Accordingly, the exemplary embodiments of the invention, as set forth above, are intended to be illustrative, not limiting. Various changes may be made to the invention without departing from the spirit and scope thereof.